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UNIE VAN SUID-AFRIKA

DEPARTMENT OF MINES DEPARTEMENT MYNWESE

GEOLOGICAL SURVEY
GEOLOGIESE OPNAME

THE SILLIMANITE DEPOSITS IN NAMAQUALAND NEAR POFADDER

BULLETIN 33

by

D. H. de Jager and J. W. von Backström

Met 'n opsomming in Afrikaans onder die opskrif:
DIE SILLIMANIETAFSETTINGS IN NAMAKWALAND NABY POFADDER

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South Africa.

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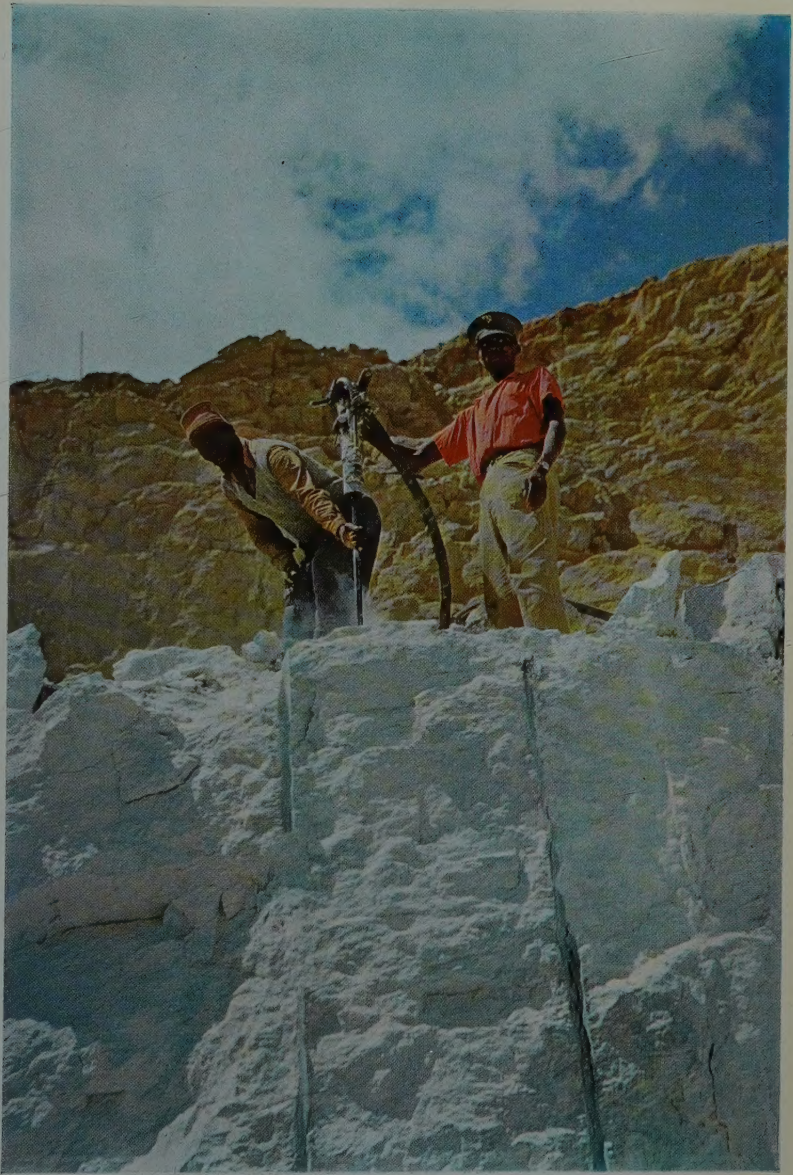

Sillimanite as exposed in Deposit No. I (Hotson). The drilling is taking place in solid sillimanite which is overlain by the gneiss visible in the background. *(With acknowledgments to Mr. R. G. Niemöller and to Messrs. A.B.C. Press, of Cape Town).*

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THE SILLIMANITE DEPOSITS
IN NAMAQUALAND NEAR POFADDER

ABSTRACT

In a hilly to mountainous, desert terrain on the slope connecting the Bushmanland Plain with the valley of the Orange River west of Pofadder, there are lenticular occurrences of sillimanite and corundum-sillimanite rock that have become an important source of refractory material. It is probable that these occurrences occupy one stratigraphic position and that they represent highly metamorphosed, lenticular patches of aluminous sediment, e.g. bauxite, in this ultrametamorphosed terrain.

Of the 11 individual deposits described, those of Swartkoppies and the No. 1 Deposit appear to contain the largest reserves. At Swartkoppies the ore is a corundum-sillimanite rock with an Al_2O_3 content of from 58 to 84 per cent.; the reserves, at the present rate of working, 800 tons per month, are sufficient for 25 years. Deposit No. 1 contains enough sillimanite rock with an Al_2O_3 content of from 58.5 to 60.04 per cent. to ensure a life of 15 years at the present production rate of 1,000 tons per month. The other deposits are either demonstrably too small, or have not been sufficiently well prospected for forecasting, to be taken into consideration in statistics of reserves, although the grade of material is in general very good.

I. INTRODUCTION

A. LOCATION OF THE DEPOSITS

The location of the deposits is indicated on a map, figure 1. The area represented on this map forms part of the northwestern Cape Province and falls within the Division of Namaqualand. The Orange River, which here forms the natural boundary between the Cape Province and South West Africa, flows through the northeastern corner of this area. Pella is a small village in the area and Pofadder, the nearest town, is situated approximately 19 miles southeast of Pella.

B. HISTORY AND SCOPE OF WORK

The corundum-sillimanite deposit on the Pella Mission

Farm has been known as such for more than 20 years, and was first described by Coetzee in 1941. D.J.L. Visser, then of the Union Geological Survey, mentioned it in a short report in 1943 dealing with the corundum occurrences of the Orange River valley. In 1955 D. de N. Wiid of the O'okiep Copper Company made a thorough investigation of this deposit for Messrs. Pella Refractory Ores S.A. (Pty.) Ltd., who have produced ore from this deposit since 1952.

During 1952, Mr. R.G. Niemöller started a systematic investigation of the mineral potentialities of the surrounding area. He succeeded in discovering most of the other sillimanite deposits known in this area as well as smaller deposits of columbite-tantalite. During the same course of investigation fairly large deposits of barytes associated with manganese and iron ore were discovered by him in the Gamsberg. These deposits as well as two occurrences of sillimanite on the farm Gams (Portion 1) were investigated in detail during August, 1955, by Coetzee after a prelimanary report was submitted by J.W. von Backström; the results were published as a Bulletin (Coetzee, 1958).

Deposits 1, 2, 3 and 4 on Hotson (Portion of Wortel), 6 and 7 on Koenabib and Deposit 8 on Gams (Portion 1) were investigated during July, 1954, by J.W. von Backström. All the deposits in the area were re-investigated by D.H. de Jager during August-September 1959.

Deposits 1, 2, 3, 4, 5, 6 and 7 have all been mined to a greater or lesser extent by Mr. R.G. Niemöller. Mr. E.A. Hayes and Mr. M.J. Hayes recently started to produce ore from Deposits 5 and 8 respectively.

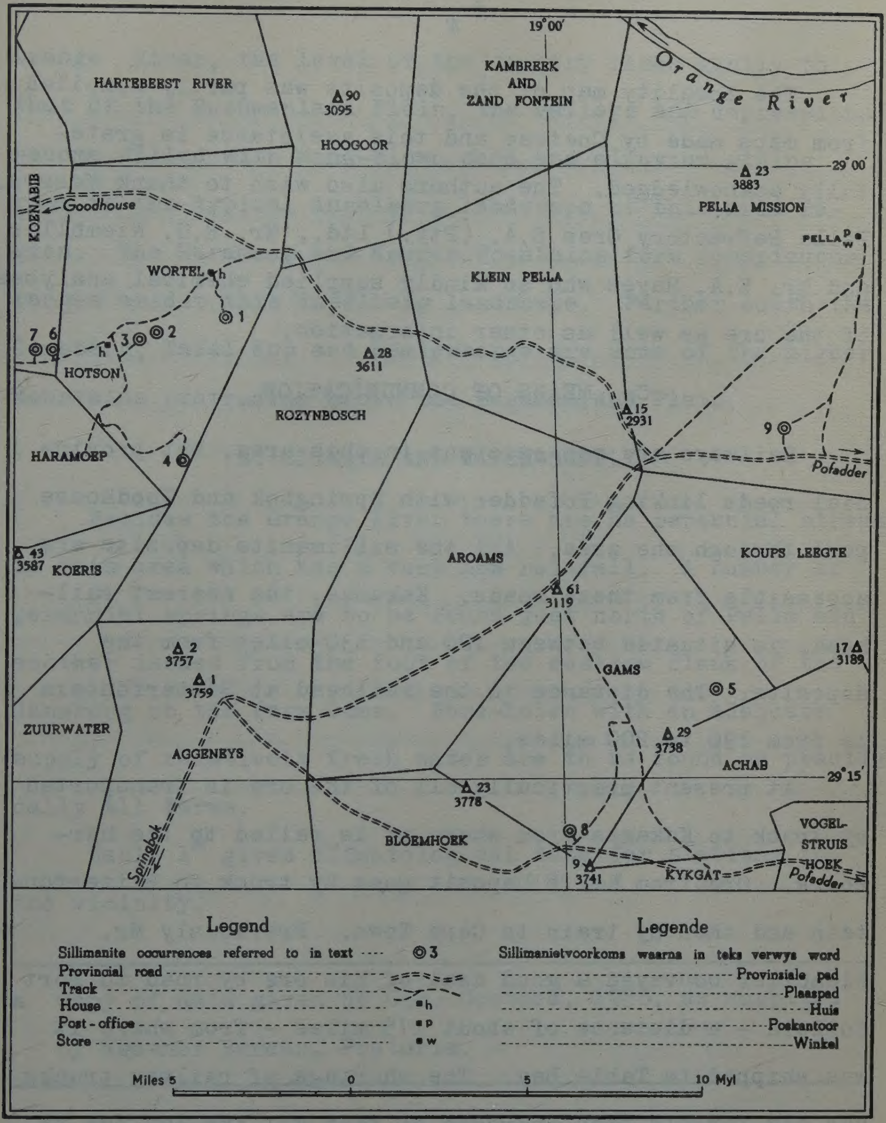

Fig.1.- Locality plan of sillimanite deposits near Pofadder.

The locality map of the deposits was partly compiled from maps made by Coetzee and this assistance is gratefully acknowledged. The authors also wish to thank Messrs. Pella Refractory Ores S.A. (Pty.) Ltd., Mr. R.G. Niemöller and Mr. E.A. Hayes who so kindly supplied chemical analyses of the ore as well as other information.

C. MEANS OF COMMUNICATION

Railways are non-existent in this area, but provincial roads linking Pofadder with Springbok and Goodhouse pass through the area. All the sillimanite deposits are accessible from these roads. Kakamas, the nearest railhead, is situated between 120 and 130 miles from the deposits. The distance to the railhead at Bitterfontein is from 190 to 200 miles.

At present practically all of the ore is transported by truck to Kakamas from where it is railed to the harbours. Ore from No. 8 Deposit goes by truck to Bitterfontein and then by train to Cape Town. Previously Mr. Niemöller conveyed a good deal of his ore by road to Port Nolloth - a distance of about 175 miles - from where it was shipped to Table Bay. The shortage of railway trucks has now largely been overcome so that all the ore can be transported via Kakamas.

II. PHYSIOGRAPHY

A. MORPHOLOGY

The country adjoining the Orange River is dissected and deeply incised giving rise to rugged mountain scenery. As one proceeds in a southerly direction, away from the

Orange River, the level of the country rises gently to that of the Bushmanland Plain, the valleys and depressions become filled with wind-blown sand and alluvium giving rise to the typical inselberg landscape of this arid region. The Haramoep and Koeris Mountains form conspicuous ranges amidst this inselberg landscape. Farther south the Gamsberg, Tafel Kop and Namiesberge are some of the higher mountains protruding above the Bushmanland Plain.

B. CLIMATE AND WATER-SUPPLY

Besides the Orange River there are no perennial streams in this area which has a very low rainfall. A number of perennial springs are to be found just north of Pella and another issues from the foot of the eastern flank of the Gamsberg on the farm Gams. Bore-holes with an adequate supply of relatively fresh water are to be found on practically all farms.

Table 1[*] gives climatological data for stations in the vicinity.

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[*] Copy of data given by C.B. Coetzee, 1958, as supplied by Weather Bureau, Pretoria.

TABLE 1

Station	Average annual precipitation	Period of observations
Goodhouse	54.6 mm. (2.15 inches)	21 years
Pella	77.5 mm. (3.05 inches)	71 years
Pofadder	98.6 mm. (3.88 inches)	18 years
	Average air temperature (°C)	
Goodhouse	Daily maximum 31.7	22 years
Goodhouse	Daily minimum 15.0	22 years
Pofadder	Daily maximum 26.1	17 years
Pofadder	Daily minimum 11.0	17 years

The area is sparcely covered by succulents and other desert shrubs. After rains the sandy flats support the growth of tall grass which provides excellent grazing for cattle and sheep.

III. GENERAL GEOLOGY OF THE AREA

For more details about this aspect the reader is referred to the works of Coetzee (1941a and 1958). He divides the rocks into two major groups viz. 1) The post-Kheis intrusive granites and 2) the pre-granitic rocks which comprise metamorphic types of the Kheis System.

1. The first group he subdivides into:

(a) An older non-gneissose granodiorite, which can be recognised in the field by its grey colour and the rounded boulders into which it weathers. (b) A younger granite-gneiss, belonging to the Namaqualand massif, having a pink colour and weathering into platy slabs. (c) An aplogranite which Coetzee considers to be an acid differentiate of the younger granite-gneiss. It may be noted that more recent work has given support to the theory that these granitic rocks did not have a magmatic origin, but represent ultrametamorphosed Kaaien sediments.

2. The rocks of the Kheis System are divided into: (a) Recrystallised quartzite which Coetzee tentatively correlates with the Kaaien Series. The light-grey, tough quartzite invariably carries sericite and it may become schistose where sericite is abundant. A thickness of 700 feet is reached in the Gamsberg. The higher mountains of the area are capped by this metaquartzite e.g. the table mountains of Wortel and Pella and also Tafel Kop and Gamsberg on Gams. (b) Conformably underlying the metaquartzite is either biotite schist or biotite gneiss. The schist, owing to the ease with which it weathers, usually occupies the sides of valleys and depressions and the lower, gentler slopes of the quartzite-capped mountains. The presence of conglomorate bands and scattered cobbles within the biotite schist led Coetzee to the conclusion that it is of sedimentary origin. These strata probably also form part of the Kaaien Series. (c) Amphibolite, which is of sedimentary origin (Coetzee, 1941a) is found throughout the area. Coetzee thinks that these rocks are to be correlated with the Marydale Series.

All the deposits of sillimanite, except possibly No. 9, occur in the mica schist immediately underlying the metaquartzite. The deposits numbered 1, 2, 3, 6 and 7 occur at variable distances apart along a line of strike of approximately 5.5 miles. It would indeed not be surprising if regional mapping should prove that all these deposits lie at a similar stratigraphic horizon as is suggested by their position below the white metaquartzite marker.

From the nature of the deposits it is obvious that the country rocks exposed exhibit the highest grade of regional metamorphism and that they have been subjected to intensive stress, compression and folding. The area is, indeed, typified by a series of synclines and anticlines.

IV. SILLIMANITE

A. COMPOSITION

Sillimanite, kyanite and andalusite are the members of a group of minerals known as the sillimanite group. They all have the same chemical composition, viz. $Al_2O_3.SiO_2$, but they differ in crystalline characteristics, and in physical and optical properties. Upon heating to high temperatures these minerals decompose into mullite ($3Al_2O_3.2SiO_2$) and free silica. Due to its high melting point (1,810°C.), mullite is a highly desirable alumino-silicate refractory. Topaz and dumortierite also give mullite when heated to high temperatures and are for this reason sometimes classed with the sillimanite group.

Sillimanite, kyanite and andalusite are fairly common in nature, but rarely occur as commercial deposits. Sillimanite occurs in metamorphic rocks such as schist, gneiss, hornfels and slate.

B. SPECIFICATIONS AND USES

The minerals of the sillimanite group have found widespread refractory uses because of their ability to withstand high furnace temperatures without reacting with the material being melted or with fluxes and furnace gases.

Up to the end of World War II, Indian kyanite dominated this field. Sharp price increases and supply difficulties led to the opening up of several East African kyanite deposits.

Before the war little use was made of the natural mineral sillimanite. A little synthetic sillimanite was used in sparkplug insulators, pyrometric tubes and laboratory porcelains. After the war a deposit of massive sillimanite boulders was developed in India by a British firm of glass manufacturers for the original purpose of sawing large glass tank blocks of superior corrosion resistance from them. Clay-bounded sillimanite bricks were also manufactured. The demand for natural sillimanite has since grown steadily and today the South African deposits are in full production to cope with this demand. The sillimanite is mainly used in glass-house refractories, electric and forging furnaces, high-temperature cements and cement kiln linings.

Specifications for the minerals are largely established by the purchaser to meet his particular needs. There are, however, some general specifications to which the raw material has to conform in order to be acceptable as refractory. Associated mineral impurities must be removed in some way, but the preparatory treatment of the ore depends on the nature, extent and intimacy of intergrowth of the associated undesirable minerals. In the case of the Namaqualand deposits careful hand-sorting is usually sufficient to ensure a pure ore of fairly uniform grade.

Freedom from associated minerals is not always essential. Such minerals as corundum, diaspore and pyrophyllite may even be beneficial as is the case with the Pella ore which contains abundant corundum. Quartz, because of its inversions, should be kept as low as possible. Moderate amounts of muscovite can be tolerated, although alkali-bearing minerals are undesirable. Iron compounds should be kept as low as possible since this element acts as a flux and causes decolouration. Tourmaline, which was noticed in the ore from No. 5 Deposit, should also be avoided since it acts as a powerful flux.

A chemical analysis is usually carried out on a representative sample of each shipment received by the purchaser. This gives an indication of the mineralogical composition of the ore, which in turn to a large extent determines the refractory properties. In addition to the chemical analysis, the percentage loss in weight upon ignition is determined. The presence of clay minerals which are undesirable - usually increases the loss on ignition. Ore containing clay minerals is usually much softer and can therefore be discarded by hand-sorting.

The alumina content of the ore is of prime importance and should not be less than 60 per cent. on the calcined basis. The iron oxide content should be less than 0.2

per cent. if the ore is to be used in the glass and electrical porcelain industries. A titania content of more than 2 per cent. is regarded as high.

C. MARKETING AND PRICES

There is only a small demand for sillimanite in South Africa and the bulk of the ore is exported overseas. Ore is mainly exported to the United Kingdom, Germany and Japan. Only a very small portion has so far been exported to the United States of America, because American buyers prefer the Indian and East African kyanite.

The prices realised depend largely on grade-size and on the quality of the material. For material supplied in lumps the price is usually in the vicinity of £16 per long ton F.O.B.

Table 2 gives some information * regarding the production, sales and prices realised for sillimanite and allied minerals from the Union of South Africa and South West Africa for the period January, 1949, to June, 1959.

---

* Figures obtained from "Minerals", Dept. of Mines Quarterly Information Circular.

TABLE 2

UNION OF SOUTH AFRICA

Year	Production Tons (2000 lbs.)	Local Sales		Exports	
		Tons(2000lbs.)	F.O.R. Value(£)	Tons (2000lbs.)	F.O.B. Value(£)
1949	An[1] 4,673	4,673	5,329		
1950	An/Sil. 8,320	8,320	9,418		
1951	An/Sil. 2,613	10,816	10,624	1,714	15,242
1952	An/Sil. 21,477	7,369	36,363	5,074	42,969
1953	An/Sil. 11,772	5,758	32,950	3,034	30,960
1954	An/Sil. 18,174	6,965	35,406	7,187	83,824
1955	An/Sil. 19,359	6,817	34,087	10,106	121,605
1956	An/Sil. 30,244	8,133	50,359	19,679	225,975
1957	An. 17,799	4,352	23,810	5,368	53,412
	Sil. 31,711	1,698	16,325	29,332	388,119
1958	An. 14,587	5,831	43,774	3,297	33,514
	Sil. 19,912	342	4,278	20,516	282,585
1959 (Jan. to June)	An. 1,883			330	3,300
	Sil. 15,541	1,010	11,736	13,472	183,391

SOUTH WEST AFRICA

Year	Exports (Kyanite/Sillimanite)	
	Tons(2000lbs.)	F.O.B.value(£)
1952	2,362	27,239
1953	1,395	14,850
1954	24.1	246
1955	75	725
1956	905	8,496
1957	4,180	43,199
1958	2,777	25,519
1959(Jan.to June)	885	8,850

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[1] An. = Andalusite, Sil. = Sillimanite.

V. THE SILLIMANITE DEPOSITS

A. DEPOSIT NO.1

This deposit is located on the farm Hotson (portion of Wortel), at the foot of a high mountain range built by quartz-mica schist and capped by hard, white metaquartzite. It occurs against the northern slope of the high range which has a fall of 1 in 3. (See accompanying map (folder 1) and plate I.)

The sillimanite body is lenticular in shape both in plan and in section and measures about 260 feet along its strike and 140 feet across its maximum width. Altogether four diamond drill-holes have so far been sunk. These are located on the four sides of the deposit (see map). All four of them penetrated the sillimanite at different depths. The two holes on the southern and northern flanks revealed thicknesses of 130 feet and 90 feet of sillimanite respectively. The holes near the narrow ends of the deposit penetrated the sillimanite at 55 feet and 54 feet respectively. Also represented on folder 1 is a section across the width of the ore-body. This was constructed from the information gathered from the drill-holes and other visible features and is probably a fair picture of what the ore-body looks like from this angle.

The sillimanite lens occurs within quartz-mica schist which dips to the south on the southern flank and to the north on the northern flank of the ore-body. The overlying metaquartzite is conformable with the schist so that the sillimanite body evidently occupies the crest of an anticline.

On the whole the sillimanite is of hard, good quality, except at the western end where patches of softer sillimanite are to be found. The good quality sillimanite is a blue-gray to gray rock which only sporadically shows dark to black spots of rutile. Stringers and clusters of mica are to be found here and there. In places the ore is stained pink to red by iron oxides.

This deposit has been in production since 1954 and approximately 62,000 short tons of sillimanite had been produced up to the end of September 1959. It is estimated that the reserves of sillimanite, taken to an average depth of 80 feet below the floor-level of the quartz at the time of investigation,amount to 190,000 short tons. For each additional foot in depth another 2,000 short tons of ore become available.

Up to the present ore has been recovered by simple quarrying. In future, however, exploitation of the ore will become increasingly more burdensome, because the remainder of the ore is at sub-ground level so that open-pit mining with subsequent hoisting of the ore to the surface will have to be resorted to. In order to recover ore that extends into the mountain - side beyond the present quarry-face, a method of tunnelling and sloping will have to be resorted to; this would necessarily result in incomplete recovery since some of the ore is to be left as supports for the hanging-wall, and the costs of extraction will be proportionately higher.

In table 3, seven analyses of ore from this deposit are given.

TABLE 3

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	L.O.I.*	Total
XXV	33.36	60.04	0.51	2.08	2.72	100.09
XXVI	35.28	60.04	0.57	0.16	4.04	100.09
XXVII	33.18	58.9	0.46	1.28	6.26	100.08
I	35.88	58.52	0.42	0.70	3.88	99.4
II	35.20	58.60	0.98	0.40	4.08	99.26
III	34.05		62.0		2.34	98.39
XXIX	35.18	58.58	0.61	1.20	4.48	100.05

*L.O.I. = Loss on ignition.

XXV.	Hard, blue-gray sillimanite, spots of rutile.
XXVI.	Medium-hard, gray sillimanite.
XXVII.	Gray, softer sillimanite.
XXIX.	Average of whole deposit.
I.	Average of 600 lbs. representing whole deposit.
II.	Gray, softer sillimanite.
III.	Gray, hard, vitreous sillimanite.

Analysts: III, XXV, XXVI, XXVII, XXIX.- McLachlan and Lazar, Johannesburg.

I.- General Refractories Ltd., England.

II.- Standard Bank of S.A.

B. DEPOSIT NO. 2

This deposit is a relatively small one. It consisted largely of a number of loose boulders most of which have since been blasted and removed. The boulders lie along an approximately straight line on a 15 degree slope at the foot of a high mountain range capped by metaquartzite. (See plate 2.)

The line of the boulders follows the quartz-sericite-sillimanite schist which builds the slopes of the mountain range. It is obvious that these boulders represent a disintegrated lens of sillimanite previously intercalated in the schist.

Upwards of 20 of these boulders were originally present ranging from approximately 2 to 50 tons in weight.

The sillimanite varies from hard and blue-gray through medium hard to soft material in different boulders. There are no appreciable reserves left at this deposit. No analyses of ore from this deposit are available.

C. DEPOSIT NO. 3

This deposit is similar in most respects to No. 2 described above except that it is considerably larger and still shows sillimanite outcropping in situ in one place. It lies along the same line of strike as Deposits 1 and 2, a few miles west of the latter deposit amongst high mountains. The deposit consists of two narrow strips of boulders of coarse sillimanite which cover parts of a steep slope built of micaceous schist. The majority of the boulders have been blasted and removed. The largest of the boulders weighed approximately 160 tons, but the majority were much smaller.

It is estimated that the reserves of ore in the form of boulders and blasted fragments amount to approximately 150 to 200 short tons. Judging from the width of the lens of 3 feet it is likely that the subsurface outcrops of the remaining portion will be very narrow and thus uneconomic and also that the roots of the original lens are probably situated at no great depth.

The sillimanite from this deposit is all very hard and high-grade material but often has a pinkish colour. The in situ deposit points to one, or possibly two, original lenses intercalated in white quartz-sericite schist. Disintegration of the lenses resulted in the formation of large boulders which tumbled down the steep slope.

Analyses of ore from this deposit are given in table 4.

TABLE 4

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	MnO	CaO	MgO	Na_2O	K_2O	L.O.I.(3)	Total
I	36.54	55.00	0.36	0.92	0.39	*	0.36	trace	0.35	0.90	5.26	100.08
II	36.24	58.63(1)	0.29	1.20	*	Nil	Nil	Nil	0.06	0.12	3.30	99.84
III	37.00	59.54(2)	0.42	1.20	*	Nil	Nil	Nil	0.12	0.22	1.48	99.96

* Not determined (1) 60.6 calcined (2) 60.45 calcined (3) Loss on ignition.

I. Sample from large boulders.

II. Pink sample from large boulders.

III. Whitish sample from large boulders.

Analysts: I.- Analysed by McLachlan and Lazar, Johannesburg.

II, III.- Analysed by General Refractories Ltd., England.

D. DEPOSIT NO. 4

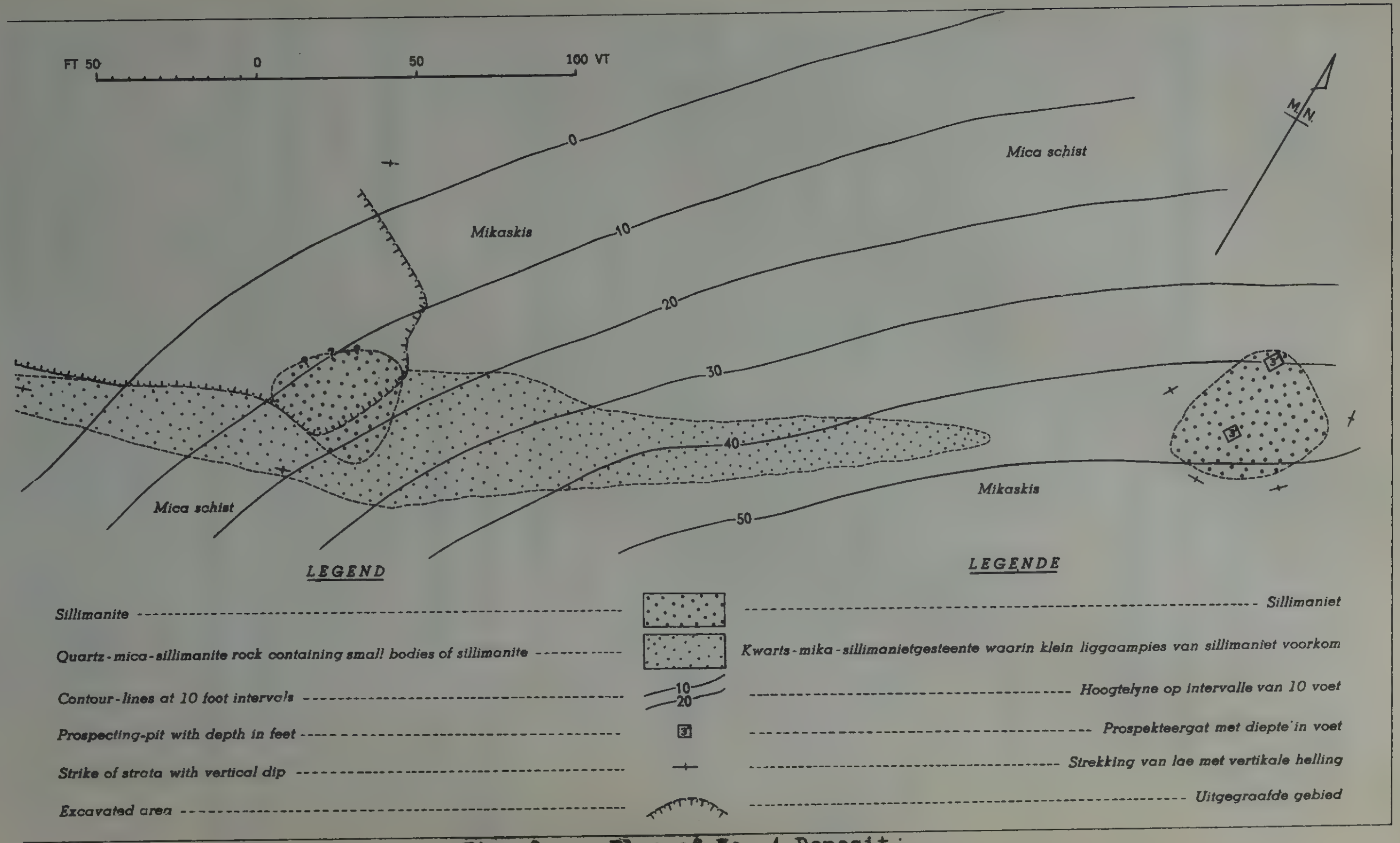
This deposit is located due south of Deposits 2 and 3 on the farm Hotson among fairly high mountains capped by hard, white metaquartzite. It consists of two fairly large bodies of sillimanite outcropping on a moderate slope of a range of hills consisting of quartz-mica schist. (See figure 2, and plate IV.) Some quarrying had been done at the southern sillimanite body before the present investigation was carried out.

1. The largest body is roughly triangular in plan and measures 45 feet across its widest exposed section. Diamond drill-holes revealed a width and depth of 50 feet each.

The central part consists of pale-blue, fine-grained, hard sillimanite of excellent grade. The edges and zones near the boundaries display a pale-yellow or gray-white discolouration which appears to be derived from the alteration of ilmenite and rutile. The body of sillimanite as well as the regional rocks of quartz-mica schist appear to stand vertically.

2. About 120 feet farther northeast, along the same line of strike, there is a second lenticular sillimanite body, 35 feet wide across its widest section, with an approximate length of strike of 50 feet. A diamond drill-hole revealed the thickness of this body to be only about 7 feet. Outcropping intermittently between the two larger ore-bodies are a number of small sillimanite bodies. There are indications of a parallel sillimanite body, some 20 feet distant, but it does not appear to be economically exploitable due to its small width.

The estimated available tonnage from the smaller body, to an average depth of 5 feet, is 500 short tons. For each additional foot in depth another 100 short tons become


FT 50
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LEGEND
LEGENDE
Sillimanite
Sillimaniet
Quartz-mica-sillimanite rock containing small bodies of sillimanite
Kwarts-mika-sillimanietgesteente waarin klein liggaampies van sillimaniet voorkom
Contour-lines at 10 foot intervals
Hoogtelyne op intervalle van 10 voet
Prospecting-pit with depth in feet
Prospekteergat met diepte in voet
Strike of strata with vertical dip
Strekking van lae met vertikale helling
Excavated area
Uitgegraafde gebied

Fig. 2. - Plan of No. 4 Deposit.

available. For the larger sillimanite body the ore reserves, taken to an average depth of 50 feet, are estimated to be nearly 10,500 short tons.

The analyses in table 5 are representative of material from the larger body.

TABLE 5

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	CaO	MgO	K_2O	Na_2O	L.O.I.(1)	Total
I 5ft.	35.72	57.34	0.54	0.40	0.08	0.00	0.75	0.74	0.22	4.20	99.99
II 15ft.	35.20	59.43	0.27	0.24	0.02	0.00	0.00	0.12	0.15	4.40	99.83
III 25ft.	35.86	59.44	0.28	0.26	0.02	0.00	0.00	0.34	0.15	3.62	99.98
IV 40ft.	32.29	63.11	0.19	0.44	0.03	0.00	0.89	0.12	0.10	2.68	99.85
V 50ft.	34.71	61.33	0.26	0.40	0.03	0.00	0.75	0.10	0.05	2.22	99.85
VI	38.22	54.98	0.20	0.26	*	0.42	0.00	0.60	0.24	5.28	100.20
VII	35.16	59.90	0.24	0.38	*	0.10	0.00	0.51	0.18	3.61	100.08

* Not determined. (1) Loss on ignition.

I, II, III, IV, V. Core from a vertical diamond drill-hole giving depth of sample in feet.

VI. Soft, white sillimanite.

VII. Hard, blue-gray sillimanite.

Analysts: I to V - McLachlan and Lazar, Johannesburg.
VI, VII - J. Muller, Cape Town.

From the core analyses it can be seen that the quality of the ore increases with depth with only a slight deterioration near the contact at 50 feet.

E. DEPOSIT No. 5

This deposit is located on Gams (Portion 2) 1.9 miles northeast of the Tafel trigonometrical beacon. Originally the deposit had the form of an inselberg of sillimanite rock projecting above the sand-covered plain. This inselberg has since been levelled and ore is at present being extracted from an open pit. The deposit measures about 110 feet along its maximum length of strike and has a width of approximately 58 feet. (See figure 3.) Two diamond drill-holes on the northern margin of the deposit revealed thicknesses of 15 and 32 feet of sillimanite respectively.

Impurities such as quartz, mica and tourmaline were noted. Careful hand-sorting of the ore is required in order to secure a uniform grade for the market. The sillimanite is similar to that of other deposits, being light-gray to bluish-gray in colour and stained pink to reddish in places. The ore is generally hard and tough but patches of softer sillimanite were also noted.

Mr. R.G. Niemöller started the production at this deposit, but abandoned it later. Messrs. Hayes resumed production at the beginning of 1959. A total of about 2,150 tons of ore had been produced up to the end of September, 1959.

About 300 yards due west of this deposit there is a small range of low inselbergs consisting of quartz-mica schist and containing small lenses of sillimanite, which due to their small size are not considered to be of any commercial value. Two small outcrops about 800 yards due east and southeast respectively of the main deposit seem to lack the quantity and quality of sillimanite to be of economic importance.

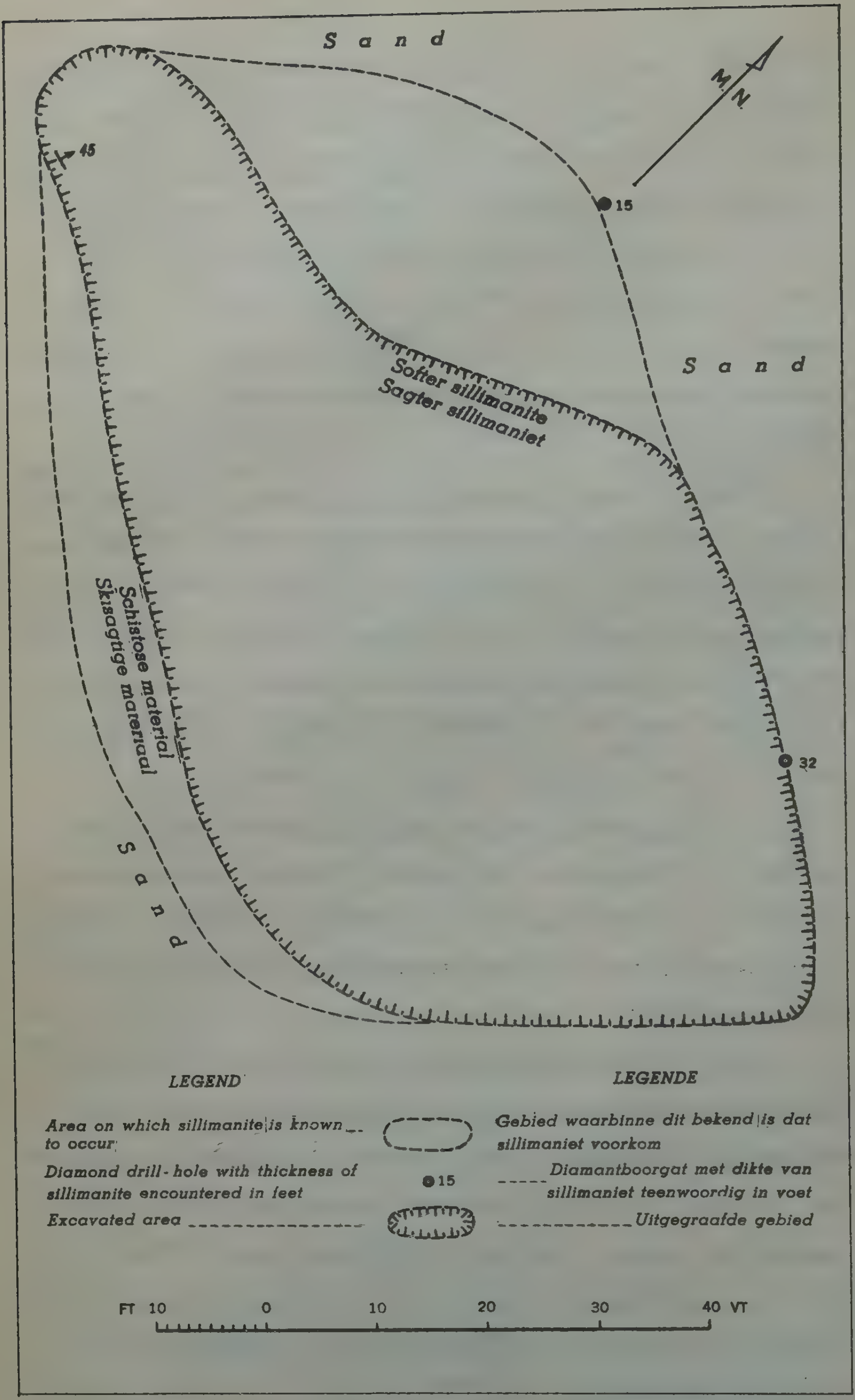
Sand
M/N
45
15
Sand
Softer sillimanite
Sagter sillimaniet
Schistose material
Skisagtige materiaal
32
Sand
LEGEND
LEGENDE
Area on which sillimanite is known to occur
Gebied waarbinne dit bekend is dat sillimaniet voorkom
Diamond drill-hole with thickness of sillimanite encountered in feet
15
Diamantboorgat met dikte van sillimaniet teenwoordig in voet
Excavated area
Uitgegraafde gebied
FT 10 0 10 20 30 40 VT

Fig. 3. - Plan of No. 5 Deposit.

It is estimated that ore reserves, taken to an average depth of 20 feet, amount to about 6,500 tons. Of this amount about 5,200 tons will be marketable. For each additional foot in depth below 20 feet another 350 tons of crude ore become available.

Analyses of ore from this deposit are given in table 6.

TABLE 6

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	CaO	MgO	Na_2O	K_2O	L.O.I.(3)	Totals
I	35.40	59.70(1)	0.36	2.30	*	0.00	0.00	0.08	0.26	1.38	99.48
II	36.33	59.15(2)	0.18	2.30	*	trace	trace	0.07	0.16	1.45	99.64
III	37.26	55.59	1.87	2.20	0.18	0.00	0.69	0.19	0.78	1.34	100.10
IV	35.60	59.10	0.26	2.10	*	0.00	0.12	*	*	2.16	99.34

* Not determined.

(1) 60.50 calcined (2) 60.00 calcined (3) Loss on ignition

I. Representative sample of a shipment of 203 tons.

II. Residual boulder material.

III. Representative sample of a shipment of 236 tons.

IV. 20 lb. sample of chipped ore.

Analysts: I, II – General Refractories Ltd., England.
III – McLachlan and Lazar, Johannesburg.
IV – J. Muller, Cape Town.

F. DEPOSIT NO. 6

This large lenticular body of sillimanite occurs on Koenabib on the same line of strike as Deposits 1, 2, 3 and 7. It is exposed over 300 feet of strike on the southern side of a small ridge trending east-west. The body dips distinctly towards the north at 35 degrees. (See accompanying map on folder 2 and plates V and VI.)

The deposit has a central zone in which there occur irregularly - spaced pockets of good, hard, blue-gray sillimanite set in a matrix of softer, gray-yellow sillimanite. This central zone is lenticular, roughly ovaloid in outline measuring 170 by 80 feet. Surrounding the central zone is an outer concentric zone of softer, gray-yellow sillimanite admixed with sericite and grading outwards into quartz-mica schist, which forms the country rock and is part of the Kaaien Series of the Kheis System. Pegmatitic lenses up to 5 feet wide and scores of feet long follow the regional strike and occur intermittently in the quartz-sericite schist.

Post-ore deformation embraces the development of several sets of master joints and a few subsidiary joints. There are two dominant and well-defined directions; the one trends northwest, or roughly parallel to the strike, and the other trends north and dips at 65 to 75 degrees towards the east or across the strike. The set of joints parallel to the strike dips towards the north at between 35 and 40 degrees. Along these latter joints there has been considerable movement since a gouge of clay up to 2 inches thick is in evidence.

Because the direction of strike of these joints coincides or approaches closely to the direction of strike of the sillimanite body, movement along these joints would not be revealed easily. The presence of these joints considerably facilitates quarrying. It is quite possible that this post-ore deformation may have had an adverse effect on the grade required and was in part responsible for minor textural changes. Together with weathering effects which were more prominant in the outer zone, yellow staining and partial softening took place. Despite this, certain smaller portions of good and hard sillimanite may be found in this outer concentric zone, especially at depth.

The difference in elevation between the lowest exposure and the highest exposure of the central sillimanite zone is 30 feet. The inclination is 35 degrees. Thus the true thickness of this lens at its maximum development is just over 17 feet. There is good geological evidence to believe that the deposit continues to greater depth although it may also be lenticular in depth, as is usually the case. No diamond drilling has yet been undertaken in order to ascertain the depth of the deposit.

Approximately 2,900 tons of ore had been produced from this deposit up to the end of September, 1959. Mining was done by the selective quarrying of the hard, good quality sillimanite. Due to the uneven distribution of the good quality ore and the lack of knowledge about the depth of the deposit it is extremely difficult to arrive at an estimate of the ore reserves.

The results of 16 analyses of ore from this deposit are given in table 7. A mean analysis is also given.

TABLE 7

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	Li_2O	L.O.I.(1)	Total
V	33.68	60.33	0.62	1.05	Nil			*		5.78	99.20
VI	33.16	58.73	0.28	1.25	Nil			*		5.78	99.20
VII	31.54	60.91	0.43	1.10	Nil			*		5.64	99.62
VIII	33.36	58.54	0.28	1.60	Nil			*		6.04	99.82
XI	33.32	59.76	0.39	1.00	Nil			*		5.58	100.05
XII	34.28	56.30	0.94	1.70	Nil			*		5.68	98.9
XIII	30.46	63.17	0.07	0.80	Nil			*		5.54	100.04
XIV	31.14	62.14	0.28	1.00	Trace			*		5.30	99.86
XV	34.52	58.29	0.28	1.25	Trace			*		5.78	100.12
XVI	35.04	58.28	0.28	0.80	Trace			*		4.94	99.34
XVII	33.56	57.50	0.32	1.40	Trace			*		6.78	99.56
XIX	35.86	57.40	0.56	0.80	0.68	0.22		.06		4.70	100.60
XXII	33.34	60.96	1.14	0.56	*			*		6.14	100.10
XXIII	33.38	58.61	0.46	0.72	*			*		4.58	99.98
XXIV	33.36	59.49	0.41	1.04	*			*		6.56	99.90
XXVIII	33.32	59.71	0.37	2.40	*			*		4.24	100.04
Mean	33.21	59.38	0.44	1.15	-			-		5.56	99.74

* Not determined (1) Loss on ignition

V. Analysed by Standard Bank.

VI. Reddish brown and soft sillimanite. Al_2O_3 (calcined) = 62.4%. Analysed by General Refractories Ltd., England.

VII. Hard gray-white sillimanite. Al_2O_3 (calcined)=64.5%. Analysed by General Refractories Ltd., England.

VIII. Hardest and best blue-gray sillimanite. Al_2O_3 (calcined) = 62.2%. Analysed by General Refractories Ltd., England.

XI. Off-white sample, western edge. Analysed by McLachlan and Lazar, Johannesburg.

XII. Softer sample. Analysed by Standard Bank.

XIII. Hard best quality sample. Analysed by Standard Bank.

XIV to XVII. Good hard quality sillimanite. Analysed by General Refractories Ltd.

XIX. Analysed by Barclays Bank. Also tested for but not present: MnO, P_2O_5, SO_3, CO_3, C.

XXII. Hard, blue-gray sillimanite. Analysed by McLachlan and Lazar.

XXIII. White sillimanite. Analysed by McLachlan and Lazar.

XXIV. Yellow-white sillimanite. Analysed by McLachlan and Lazar.

XXVIII. Blue-gray sillimanite from largest and deepest hole in road loop. Analysed by McLachlan and Lazar.

The high loss on ignition and the relatively high alumina content that goes with it, indicate the presence of clayey material.

G. DEPOSIT NO. 7

This deposit is situated approximately 750 yards due west of Deposit No. 6. It occupies the same geological horizon as Deposit 6 and occurs in quartz-mica schist on the southern slope of an east-west trending range of hills capped by hard, white metaquartzite which dips from 45 to 60 degrees towards the north.

Two large pegmatite veins with xenoliths of quartz-mica schist and following the regional strike are found both north and south of the lens of sillimanite.

The lens of sillimanite lies on a small dome-shaped hill, which rises to an approximate height of 90 feet above an erosion valley in the west. It is bounded in the east by a saddle of quartzitic hills. (See accompanying map on folder 3 and plates VII and VIII.)

The steep slopes of the sillimanite koppie used to be covered by a residual layer of large, angular, and partly rounded sillimanite boulders, the largest of which measured 12 feet in diameter. These boulders have since been broken up. The primary deposit consists of a relatively narrow lenticular body traversing at a steep angle the centre of the koppie from northwest to southeast. The country-rock of mica schist, being relatively softer, was subjected to more comprehensive disintegration.

The sillimanite of this deposit consists of hard, high-grade material. Only a small amount of reddish-brown material which is inacceptable due to its high iron content, must be hand-sorted and removed. Softer weathered material is to be found at the upper surface of the deposit. Deleterious rutile and ilmenite, which in this region are always associated with the sillimanite, are seldom higher than 5 per cent. in individual samples whereas an overall amount of 2 per cent. is permissable.

Until further exploratory work has been done an estimate of the available reserves can only be tentative. Thus far a total of 3,600 tons of ore has been produced and sold, most of this being boulder material. In future ore will have to be obtained from the in situ deposit which is estimated to have at least 1,000 tons of ore in reserve.

In table 8 are given analyses of ore from this deposit.

TABLE 8

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	CaO	MgO	Na_2O	K_2O	L.O.I.(1)	Total
I	35.36	59.59	1.29	0.60	*	Nil		0.27	0.21	1.84	99.16
II	35.98	58.64	0.21	1.15	*	Nil		0.20	0.33	4.56	101.07
III	35.60	60.60	0.30	1.50	*	Nil		0.13	0.20	1.66	100.03
IV	31.20	65.00	0.64	1.20	*	Nil	trace	0.05	0.09	1.80	99.98
V	36.00	59.16	0.42	1.30	*	Nil	trace	0.03	0.04	1.60	98.55
VI	36.60	59.24	0.56	1.20	*	Nil	trace	0.06	0.05	1.08	98.79
VII	35.80	60.70	0.44	1.39	*	Nil	trace	0.05	0.04	1.72	100.05
VIII	35.60	60.40	0.33	1.90	*	Nil		*	*	1.0	99.23
IX	36.60	59.13	0.32	1.52	0.11	Nil		0.15	0.05	6.61	100.07
X	36.24	57.85	0.48	1.85	0.24	Nil	0.06	0.19	0.29	2.88	100.08
XI	36.65	58.77	0.80	1.40	0.16	Nil		0.25	0.35	1.68	100.06
Mean	35.60	59.92	0.52	1.36	-	-	-	0.14	0.16	2.40	100.10

* Not determined. (1) Loss on ignition.

I. Stained sample of sillimanite. Al_2O_3 (calcined) = 60.68%.

II. Al_2O_3 (calcined) = 61.4%

III. Al_2O_3 (calcined) = 61.7%

IV. Al_2O_3 (calcined) = 66.2%

V. Al_2O_3 (calcined) = 60.1%

VI. Al_2O_3 (calcined) = 59.78%

VII. Al_2O_3 (calcined) = 61.80%

VIII. Al_2O_3 (calcined) = 61%

Analysts: I to VIII - General Refractories Ltd., England.

IX to XI - McLachlan and Lazar, Johannesburg.

H. DEPOSIT NO. 8

This is a lenticular body of sillimanite occurring on the southern flank of a koppie close to the foot of the Gamsberg on Gams (Portion 1). It occurs within mica schist overlain by hard, white metaquartzite of the Kaaien Series. The lens has a maximum length of strike of 100 feet and measures 38 feet across its maximum width. (See figure 4.) The sillimanite body appears to be vertical while the schist and metaquartzite dip slightly towards the north. About 60 per cent. of the ore has to be discarded as a result of the high mica content. There are patches of good, hard, gray sillimanite however.

Production started in February, 1959, and up to the end of September, 1959, about 1,500 tons of ore had been sold. It is difficult to make an estimate of the ore reserves, since so little is known about the depth of the deposit. Area 1 (see map) is expected to have a reserve of 2,700 tons of crude ore to an average depth of 30 feet. Area 2 is expected to give another 1,000 tons of crude ore to an average depth of 5 feet. The spot-heights on the map will give an idea of the elevations involved.

On the northern flank of the same koppie there is a second sillimanite occurrence. It is intermittently exposed over a strike of about 650 feet and averages about 18 inches in width. The sillimanite occurs within brown micaceous schist and dips to the south at angles varying from place to place. The ore, which is rather soft and of poor quality, is not considered to be a potential source of sillimanite in the future.

One analysis of ore from the southern occurrence is available. The sample was obtained from a boulder and represents, like boulder material from all the other deposits, the best quality material, since the softer inferior

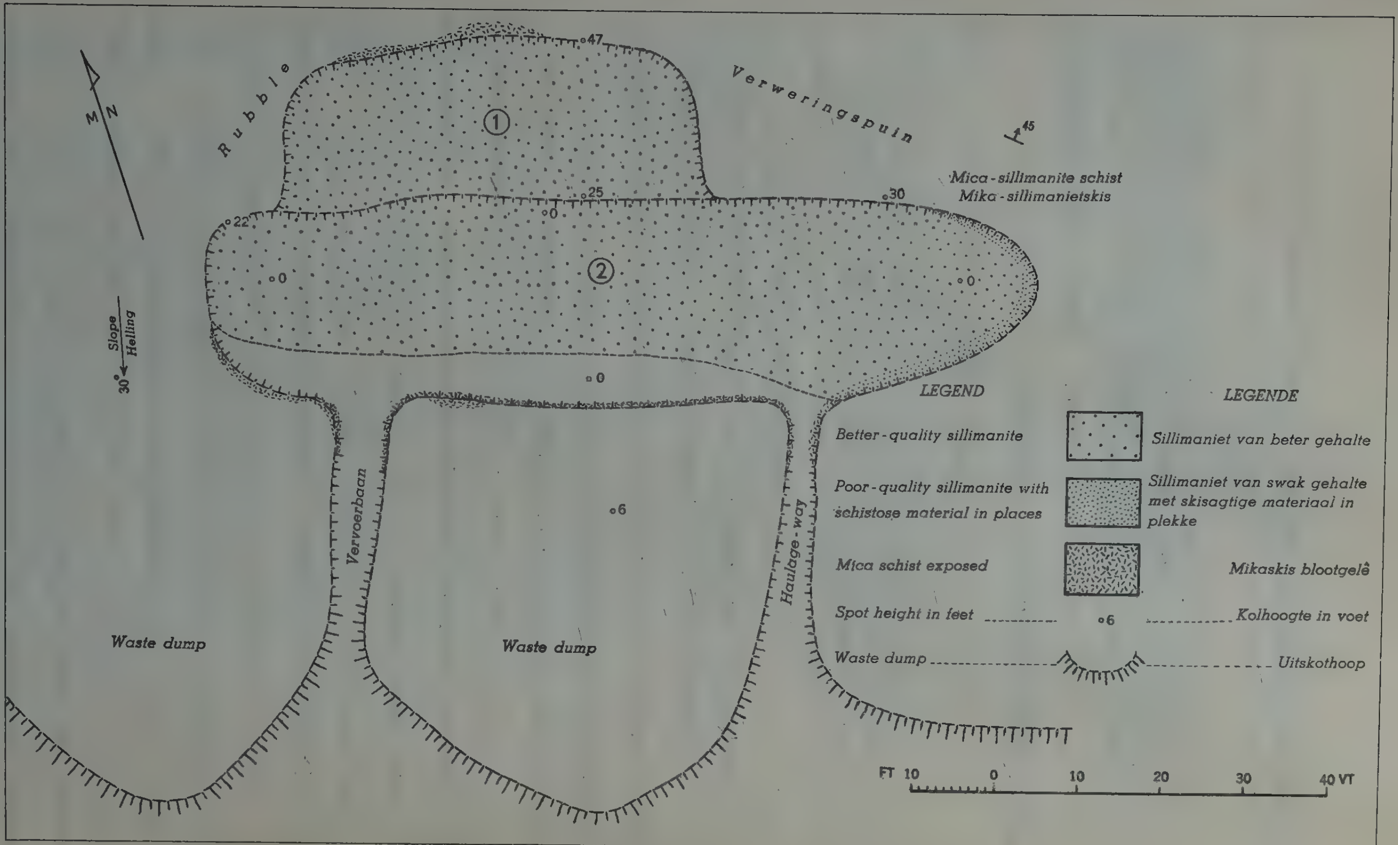

Fig. 4. - Sketch plan of No. 8 Deposit.

material succumbed to weathering much sooner.

TABLE 9

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	Na_2O	K_2O	L.O.I.	Total
35.00	59.95	0.14	1.80	trace	trace	0.07	0.31	2.19	99.46

Al_2O_3 = 61.12 per cent., calcined. Sample was analysed by General Refractories Ltd., England.

I. DEPOSIT NO. 9

This deposit actually comprises three individual deposits namely Swartkoppies, Pella East and Pella West.

1. Swartkoppies Deposit

The deposit is located in the southeastern corner of the Pella Roman Catholic Mission Farm. The main deposit forms a small, but conspicuous, black-weathering range of inselbergs protruding above a sand-covered plain and is known as the Swartkoppies deposit. It differs from the deposits so far described in that it is not monomineralic, but contains abundant corundum in addition to sillimanite.

The total length of the range of inselbergs, which strikes east-west, is approximately 1,000 feet and its maximum width about 280 feet. (See accompanying map on folder 4.) These inselbergs represent four independant, massive, well-jointed corundum-sillimanite bodies of irregular outline. Partial disintegration of these bodies led to the formation of large blocks and boulders which became dislodged and tumbled down to lower levels. It is only the extreme toughness of the corundum-sillimanite that caused it to survive the erosion that levelled the country in its immediate vicinity.

Excavations on the site of the deposit revealed the presence of two types of host-rock, viz. mica schist, which immediately underlies the ore, and granulite which in turn underlies the schist. The western ore-bodies appear to occupy the trough of a syncline in the host-rocks. (See section on folder 4.)

A total of 41 holes were drilled on the Swartkoppies site by the O'okiep Copper Company. These holes were drilled on the northern side of the range of hills and were directed towards the south at an angle of about 45 degrees. The core log from one of these holes, kindly supplied by Messrs. Pella Refractory Ores S.A. (Pty.) Ltd., was as follows and serves to illustrate a typical succession in the vicinity of the deposit.

Borehole M12: $-45^{\circ}S\ \ 20^{\circ}W$.

0' - 34'	casing; at 34' recent calcareous material.
34' - 37'	corundum-sillimanite; at 37' recent calcareous material.
37' - 48'	sand.
48' - 90'	biotite-sillimanite schist.
90' - 130'	granulite.
130' - 189'	biotite-sillimanite schist.
189' - 190'	pegmatite.
190' - 218'	biotite-sillimanite schist.
218' - 219'	pegmatite.
219' - 243'	biotite-sillimanite schist.
243' - 245'	pegmatite.
245' - 261'	biotite-sillimanite schist.
261' - 262'	quartz with pyrite.
262' - 267'	granulite.
267' - 291'	biotite-sillimanite schist.
291' - 294'	pegmatite with pyrite.
294' - 300'	biotite-sillimanite schist.

The rocks that build the nearby hills and mountains consist of granite-gneiss, metaquartzite and amphibolite and probably belong to the Kaaien Series of the Kheiss System.

Sillimanite and corundum are the two chief constituents of the ore, with ilmenite and rutile as the accessory minerals. These minerals usually occur intimately intergrown, but sillimanite frequently occurs alone in the form of veins. The relative abundance of the constituent minerals varies considerably from place to place. Sillimanite may be in excess of corundum or *vice versa*. This fact is clearly illustrated by the chemical analyses of the ore; the alumina content varies from 58 per cent. in ore consisting almost entirely of sillimanite to 85 per cent. in ore where corundum predominates. Titanium-rich ore tends to be concentrated in certain parts near the centre of the deposit.

Wiid, 1955, calculated an average mineral composition for the whole deposit from 29 chemical analyses of ore from all over the deposit. He gives the average composition as follows:

Sillimanite	Corundum	Ilmenite	Rutile	Total
53%	41%	2.77%	1.19%	97.96%

Wiid further divides the ore into 3 distinct types which could be recognised easily in the hand specimen. They are: 1) The coarse, veinlike variety consisting almost entirely of sillimanite. 2) A light-grey to mottled type consisting of both sillimanite and corundum, with sillimanite in excess. 3) A dark-grey, fine-grained variety also containing both minerals but with corundum in excess. These 3 types are fairly well segregated within the deposit; selective quarrying with subsequent hand-sorting should therefore suffice to separate these 3 types fairly cleanly.

At present the ore is marketed after the titanium-contaminated fraction has been sorted out by hand. This ore is at the moment being stock-piled, should it become possible in future to have it economically beneficiated. Research in this direction is at present being carried out by Mr. R. Richardson of the O'okiep Copper Company. This research is aimed not only at separating the titanium-bearing fraction from the corundum and sillimanite, but also at separating corundum and sillimanite from each other.

Ore is at present being recovered by mudblasting the jointed blocks and boulders to the required size (12"-15"). An attempt to crush this extremely hard and tough ore at the Swartkoppies site proved unsuccessful due to the abnormal wear which was inflicted upon the crushing machinery.

From June, 1952, to October, 1959, approximately 54,000 tons of ore were sold.

This deposit is estimated to have in reserve another 255,000 short tons of ore. This figure is based only on ore that outcrops. The diamond drill-holes did encounter ore at depth, but in most cases either drilling was abandoned as soon as ore was struck, or the ore zone proved to be only from 1 to 4 feet thick. Consequently it is not at all possible to make an estimate of the hidden reserves. The western part of the deposit is underlain by schist and does not continue to any appreciable depth. The eastern part may well have substantial amounts of ore in reserve at depth.

Analyses of ore from this deposit are given in table 10. Analyses S1 to S7 and 3862 to 3873 were copied from Wiid's report and analyses I to VII were kindly supplied by Messrs. Pella Refractory Ores, S.A. (Pty.) Ltd. The latter analyses are of representative samples of shipments of 100 tons or more each.

TABLE 10

Sample Nó.	SiO_2	Al_2O_3	FeO	TiO_2	Ign. Loss.
S1	10.22	83.38	1.69	2.40	n.d.
S2	12.00	82.30	1.10	1.65	n.d.
S3	25.12	67.54	1.91	2.45	n.d.
S4	4.24	83.19	0.74	7.00	n.d.
S5	12.94	79.60	1.30	2.45	n.d.
S6	10.80	83.98	0.60	1.55	n.d.
S7	25.76	71.94	1.54	1.45	n.d.
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Ign. Loss.
3862	33.76	60.16	1.44	2.00	1.45
3863	12.76	81.72	0.58	2.30	1.86
3864	15.42	76.15	1.15	5.00	1.88
3865	26.72	68.30	2.40	1.70	0.74
3866	16.30	79.72	0.78	1.90	0.57
3867	16.82	77.11	0.69	2.00	1.27
3868	14.32	78.50	0.50	3.00	1.21
3869	17.50	74.38	1.12	3.50	1.52
3870	17.50	78.02	1.48	2.00	0.97
3871	34.76	58.79	2.01	0.80	1.21
3872	32.10	58.85	2.55	2.30	1.31
3873	34.90	59.43	1.97	2.00	1.65
I	18.5	74.9	1.32	3.55	1.08
II	17.3	75.8	0.62	3.82	1.75

Table 10 (continued)

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Ign. Loss
III	19.6	73.5	0.75	4.02	1.10
IV	20.8	73.5	1.13	2.01	1.30
V	17.3	75.0	0.75	3.74	2.20
VI	17.8	74.6	0.85	3.77	1.95
VII	16.5	76.5	0.78	3.56	1.85

No's. S1 to S7 were analysed by D. Steyn of the O'okiep Copper Company Ltd.

No's. 3862 to 3873 were analysed by Barclays Bank.

No's. I to VII - Analyst unknown.

2. Pella West Deposit

Practically all the ore from this deposit has been removed. The deposit, located some distance due west of the Swartkoppies deposit, originally consisted of a large number of loose boulders scattered over an area of approximately 200,000 square yards. These boulders varied in size from less than a foot up to 10 feet in diameter. The composition of the ore was very similar to that of the Swartkoppies deposit.

The boulders rested on an eroded surface of gneiss and they obviously represented the remnants of an ore-body.

About 18,000 tons of ore were produced from this deposit and today only a few boulders remain.

3. Pella East Deposit

This deposit is located approximately half-a-mile due east of Swartkoppies and consists of a small pile of corundum-sillimanite blocks protruding above the surrounding sand-covered plain. Trenches at the ends of the outcrop revealed the presence of similar blocks at a depth of 10 to 15 feet.

This deposit is probably similar to that of Swartkoppies in that it may be a deposit in place and not merely remnant boulders as is the case with the Pella West deposit.

No analyses of ore from this deposit are available, but it resembles the Swartkoppies ore closely in the hand specimen; it is therefore probably of similar composition. It may be worth while to have this deposit explored further.

VI. ORIGIN OF THE ORE

Only the northern portion of this area has so far been geologically surveyed, but although the remainder is not as well known, it is certain that the rocks in this area were subjected to ultrametamorphism and probably granitisation.

Read (1956) ascribes the origin of the Pella corundum-sillimanite deposit to a process of migmatisation, which in turn is closely related to granitisation. He suggests that this deposit "might be due to subtractions connected with metamorphic differentiation operating on a grand scale in the juicy setting of migmatisation". All the workers in this area namely, Coetzee, Wiid and the present authors are of the opinion that regional mapping will prove all the sillimanite deposits to lie in the same stratigraphic horizon. This feature will be difficult to account for in Read's theory.

The authors further agree with Coetzee (1958) and Wiid (1955) that there was present in the original sediments an aluminous zone from which the sillimanite deposit originated. The aluminous sediments, possibly bauxite, probably existed in the form of lenses within the original sediments. These lenses would explain why the sillimanite occurs in the form of individual bodies and not as a continuous layer.

Hall and Nel (1926) described an occurrence of corundum-sillimanite rock in the norite of the Bushveld Igneous Complex and they are of the opinion that it originated as a result of the interaction of noritic magma with an aluminous sediment. It is very doubtful whether a similar process was operative in the case of the Pella ore, since there is no evidence that any material, e.g. alkalis, was introduced. At this stage, therefore, one is forced to agree with Coetzee (1941) that the Pella ore was formed by the metamorphism of a bauxite, without the addition of material from outside. The remarkable similarity in chemical composition between the Pella ore and certain bauxites, supports this view. The pure sillimanite deposits are also thought to be the metamorphic products of aluminous sediments, which were not necessarily bauxite, but perhaps aluminous clay. The difference in composition between the Pella ore and the pure sillimanite ore of the other deposits may also be explained, as Wiid (1955) suggests, as a general phase difference in the metamorphism of the area. Read objects to the idea of metamorphosed bauxite because, he says, "it raises formidable problems of palaeogeography and stratigraphy that have not been adequately, if at all, regarded." Considerations of this kind, however, cannot be entertained to the exclusion of others at this stage of our knowledge of the area.

VII. FUTURE OUTLOOK

Of all the sillimanite deposits only the Swartkoppies and No.1 Deposits can at the moment be regarded as reliable future sources of the material. The average monthly production for the Swartkoppies deposit over a period of seven years was approximately 800 tons. At this rate the Swartkoppies deposit should not be exhausted within the next 25 years. The average monthly production from the No.1 Deposit over a period of 5½ years was approximately 1,000 tons. If this rate is maintained the reserves should last for another 15 years. Deposit No.4 has a fair amount of ore in reserve, but not enough to ensure a working life of very much longer than a year. Deposits 6 and 7 as well as that of Pella East may prove to have substantial amounts of ore in reserve, but until further exploratory work has been done, they cannot be relied upon.

Table II gives a summary of the production and reserves of ore. The reserves are those that existed at the end of September, 1959, and the amount of ore produced is also for the period ending September, 1959.

TABLE 11

Deposit	Proved Reserves	Ore Produced, Tons (2000lbs)		Expected Life
	Tons (2000 lbs)	Total	Average Monthly	Duration
No. 1	190,000	62,000	1,000	15 years
No. 2	Negligible	-	-	-
No. 3	Negligible	-	-	-
No. 4	11,000	-	(1,000)	11 months
No. 5	6,500	2,150	(500)	13 months
No. 6	-	2,900	-	-
No. 7	At least 1,000	3,600	(1,000)	1 month
No. 8	3,700	1,500	(500)	7 months
Swartkoppies	255,000	54,000	800	25 years
Pella West	Negligible	18,000	-	-
Pella East	-	-	-	-

N.B. The average monthly production figures for deposits 4, 5, 7 and 8 are hypothetical and merely serve to evaluate an expected life duration.

The demand for sillimanite ore has shown considerable fluctuation during the past. At present there is a fairly steady and growing demand, especially from Japan. It is rather doubtful whether Japanese industries are utilising all the ore being purchased; it is more likely that some ore is being stockpiled. It is therefore only reasonable to expect some decrease in the demand from this country inthe near future.

During the last twenty years the more superior refractories based on chrome, magnesite and dolomite have been used extensively in fields previously dominated by aluminous and acid refractories. In order to attain its

present status in the refractories field, it is of utmost importance that only the best quality sillimanite should be marketed.

OPSOMMING IN AFRIKAANS

DIE SILLIMANIETAFSETTINGS IN NAMAKWALAND NABY POFADDER

I. INLEIDING

Die lokaliteite van die voorkomste word op figuur 1 aangedui.

Die korund-sillimanietafsetting op Pella is reeds meer as 20 jaar as sulks bekend en word sedert 1952 deur Pella Refractory Ores S.A. (Pty.) Ltd. ontgin. Die ander sillimanietafsettings is sedert 1952 deur mnr. R.G. Niemöller ontdek. Afsettings 1, 2, 3, 4, 5, 6 en 7 is dan ook in n mindere of meerdere mate deur mnr. Niemöller ontgin.

Erts word oor n afstand van 120 tot 130 myl per vragmotor na Kakamas vervoer, vanwaar dit dan per trein na Kaapstad versend word.

II. FISIOGRAFIE EN ALGEMENE GEOLOGIE

Die gemiddelde reënval in hierdie gebied is ongeveer 75 m.m. per jaar en water word hoofsaaklik van boorgate verkry.

Die streek langs die Oranjerivier is erg versny en is ru en bergagtig. Suidwaarts word die landskap inselbergagtig en gaan dan geleidelik oor tot die Boesmanlandvlakte.

Die gesteentes in die gebied is deur Coetzee (1941a) in twee hoofgroepe verdeel, nl. 1) die intrusiewe granietsoorte jonger as die Sisteem Kheis, en 2) die voor-granitiese gesteentes bestaande uit metamorfe tipes van die Sisteem Kheis.

1. Die eerste groep bestaan uit ŉ ouer, nie-gneisagtige granodioriet, ŉ jonger, ligrooskleurige granietgneis van die Namakwalandmassief en ŉ aplograniet.

2. Die gesteentes van die Sisteem Kheis bestaan uit die volgende:
   (a) ŉ Metakwartsiet wat ŉ dikte van 700 voet bereik en wat tot die Serie Kaiing behoort.
   (b) Biotietskis of biotietgneis lê konkordant onder die metakwartsiet en behoort waarskynlik ook tot die Serie Kaiing.
   (c) Amfiboliet, wat moontlik tot die Serie Marydale behoort, word dwarsdeur die gebied aangetref.

Die gesteentes was onderworpe aan regionale metamorfose wat ook ŉ reeks antikliene en sinkliene laat ontstaan het. Meer onlangse navorsing het die gedagte laat posvat dat selfs die groep gesteentes onder (1) hierbo beskryf, hulle ontstaan aan ultrametamorfose en granitisasie wyt.

III. SILLIMANIET

Sillimaniet, wat in gesteentes soos skis, gneis, horingfels en lei voorkom, het net soos andalusiet en kianiet die skeikundige samestelling $Al_2O_3 \cdot SiO_2$.

Dit word gebruik as ŉ vuurvaste materiaal en moet om dié rede vry wees van kwarts, alkaliminerale, yster- en titaanverbindings, toermalyn en ander minerale wat as smeltmiddels kan dien. Kleiminerale is ook onwenslik. Minerale soos korund en pirofilliet dra by tot die vuurvastheid. Sortering met die hand is gewoonlik voldoende om ŉ eenvormige, hoëgraadse erts van die afsettings in hierdie gebied te verseker.

Etlike duisende tonne sillimaniet word jaarliks na die Verenigde Koningkryk, Duitsland en Japan uitgevoer. Die prys is gewoonlik in die omgewing van £16 per grootton V.A.B. vir goeie gehalte materiaal in brokstukke van ongeveer 6 tot 12 duim in deursnee.

IV. DIE SILLIMANIETAFSETTINGS

A. AFSETTING NR. 1

Dit kom voor as ŉ massiewe, lensvormige liggaam teen die hang van ŉ berg en lê in skis op die kruin van ŉ antiklien. Die lens is 260 voet lank, 140 voet breed en die dikte wissel van 54 tot 130 voet.

Die erts is oor die algemeen van goeie gehalte en bevat baie min onsuiwerhede in die vorm van kwarts, rutiel en mika.

Ongeveer 62,000 ton erts is tot die end van September 1959 deur gewone steengroefmetodes ontgin. Na beraming was die reserwes aan die begin van Oktober 1959 sowat 190,000 ton.

Analises van hierdie erts het getoon dat die aluminainhoud wissel van 58.5 tot 60.04 persent.

B. AFSETTING NR. 2

Hierdie afsetting het oorspronklik bestaan uit ŉ liniêr verspreide aantal residuele blokke van sillimaniet aan die voet van ŉ berg. Die meeste van die blokke is sedertdien opgebreek en weggeneem. Die gehalte van die sillimaniet het gewissel van goeie harde tot sagter materiaal.

Die blokke is waarskynlik die oorblyfsels van ŉ sillimanietliggaam wat uit die skis verweer het. Daar is geen noemenswaardige reserwes nie.

C. AFSETTING NR. 3

Die afsetting het bestaan uit twee smal strepe sillimanietblokke wat versprei gelê het teen die steil hang van ŉ berg bestaande uit skis wat bedek word deur metakwartsiet. Die meeste van die blokke is sedertdien opgebreek en weggeneem. Die blokke is waarskynlik die oorblyfsels van ŉ lens waarvan ŉ klein gedeelte nog teenwoordig is in die vorm van ŉ ertsliggaam, 3 voet dik, wat nog in plek is.

Die sillimaniet is van harde, goeie gehalte en effe rooi gekleur. Analises van die erts het getoon dat die alumina-inhoud wissel van 55.0 tot 59.5 persent.

D. AFSETTING NR. 4

Dit bestaan uit twee ertsliggame, ingesluit in kwartsmikaskis teen die hang van ŉ berg; bo-op die skis volg metakwartsiet.

Die grootste ertsliggaam is driehoekig in plan, omtrent 45 voet op sy breedste en 50 voet lank. Dit bestaan hoofsaaklik uit harde, ligblou sillimaniet van goeie gehalte.

Die kleinste ertsliggaam is sowat 35 voet in deursnee en 50 voet lank met ŉ dikte van slegs 7 voet.

Aan die begin van Oktober 1959 was die beraamde ertsreserwes vir die twee liggame tesame ongeveer 11,000 ton. Analises van boorkern van die groot ertsliggaam het getoon dat die kwaliteit van die sillimaniet met toenemende diepte verbeter.

E. AFSETTING NR. 5

Hierdie afsetting was oorspronklik ꞌn klein inselberg omring deur sand. Erts word teenswoordig uit ꞌn oop gat in die grond gehaal. Die huidige lengte van die afsetting is 110 voet, die breedte is 58 voet en die gemiddelde dikte is 15 voet. Onsuiwerhede soos kwarts, mika en toermalyn is in die erts opgemerk.

Die ertsreserwes, soos beraam aan die begin van Oktober 1959, bedra ongeveer 6,500 ton.

F. AFSETTING NR. 6

Hierdie is ꞌn lensvormige liggaam wat voorkom en geleidelik oorgaan in kwarts-mikaskis. Dit bestaan uit ꞌn sentrale sone, ongeveer 170 by 80 voet, waarin daar onreëlmatig verspreide neste van goeie, harde sillimaniet voorkom. Die sentrale sone word omring deur ꞌn konsentriese buitenste sone bestaande uit minderwaardige sillimaniet.

Ongeveer 2,900 ton sillimaniet is hiervandaan geproduseer. Weens die aard van die verspreiding van die sillimaniet van beter gehalte kon die reserwes nie bepaal word nie.

Die gemiddelde persentasie alumina in die erts van hierdie afsetting, soos bepaal van 16 verskillende analises, is 59.38.

G. AFSETTING NR. 7

Die lensvormige ertsliggaam vorm die kruin van ʼn koepelvormige koppie wat bestaan uit mikaskis en waarvan die hange bedek was met residuele sillimanietblokke. Alhoewel die sillimaniet oor die algemeen hard en hoëgraads is, bevat dit ook heelwat rutiel en ilmeniet in plekke.

Sowat 3,600 ton erts is reeds geproduseer en reserwes word geskat op ten minste 1,000 ton. Die gemiddelde persentasie alumina in die erts van hierdie afsetting is 59.92.

H. AFSETTING NR. 8

Die afsetting is lensvormig en kom voor in mikaskis. Dit het ʼn lengte van 100 voet en ʼn maksimale breedte van 38 voet.

As gevolg van die hoë mika-inhoud is die grootste gedeelte van die erts ongeskik vir die mark. Reserwes was aan die begin van Oktober 1959 sowat 3,200 ton.

I. AFSETTING NR. 9

Daar is in werklikheid drie individuele afsettings, nl. Swartkoppies, Pella-Wes en Pella-Oos.

1. Swartkoppies

Hierdie voorkoms bestaan uit ʼn klein reeks inselberge omring deur sand. Die totale lengte is sowat 1,000 voet en die breedte 280 voet.

Die erts bestaan hoofsaaklik uit ʼn mengsel van korund en sillimaniet, met heelwat ilmeniet en rutiel op plekke. Die alumina-inhoud wissel van omtrent 58 to 84 persent.

Die reserwes, soos beraam aan die begin van Oktober 1959, was ongeveer 255,000 ton.

2. Pella-Wes

Die grootste gedeelte van die erts is alreeds verwyder. Die afsetting het bestaan uit ŉ groot aantal residuele blokke korund-sillimaniet wat versprei gelê het oor ŉ oppervlakte van ongeveer 200,000 vierkant jaart. Dit het ongeveer 18,000 ton erts opgelewer.

3. Pella-Oos

Die afsetting bestaan uit ŉ klein hopie blokke korund-sillimaniet omring deur sand.

V. ONTSTAAN VAN DIE ERTS

Dit wil voorkom asof die afsettings op dieselfde stratigrafiese hoogte lê. Die opinie word gehuldig dat daar ŉ aluminiumryke sone in die oorspronklike sedimente was; metamorfose van hierdie aluminiumryke sediment, bv. lense van bauxiet, het die korund-sillimaniet- en sillimanietafsettings voortgebring.

VI. VOORUITSIGTE

Afsettings 1 en 9 met reserwes van 190,000 en 255,000 ton respektiewelik, blyk die enigste twee te wees waarop in die toekoms staatgemaak kan word.

Die status van sillimaniet as ŉ vuurvaste stof word teenswoordig tot ŉ groot mate bedreig deur vuurvaste stowwe soos byvoorbeeld chroom, magnesiet, en dolomiet en dit is dus van die uiterste belang dat alleenlik sillimaniet van die beste gehalte bemark word.

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Plate I.—Sillimanite Deposit No. 1. Squat lens on steep slope. Approximately 200 by 120 feet. Photograph was taken before major mining operations started.

Plate II.—Sillimanite Deposit No. 2. Note large and small boulders of sillimanite (S).

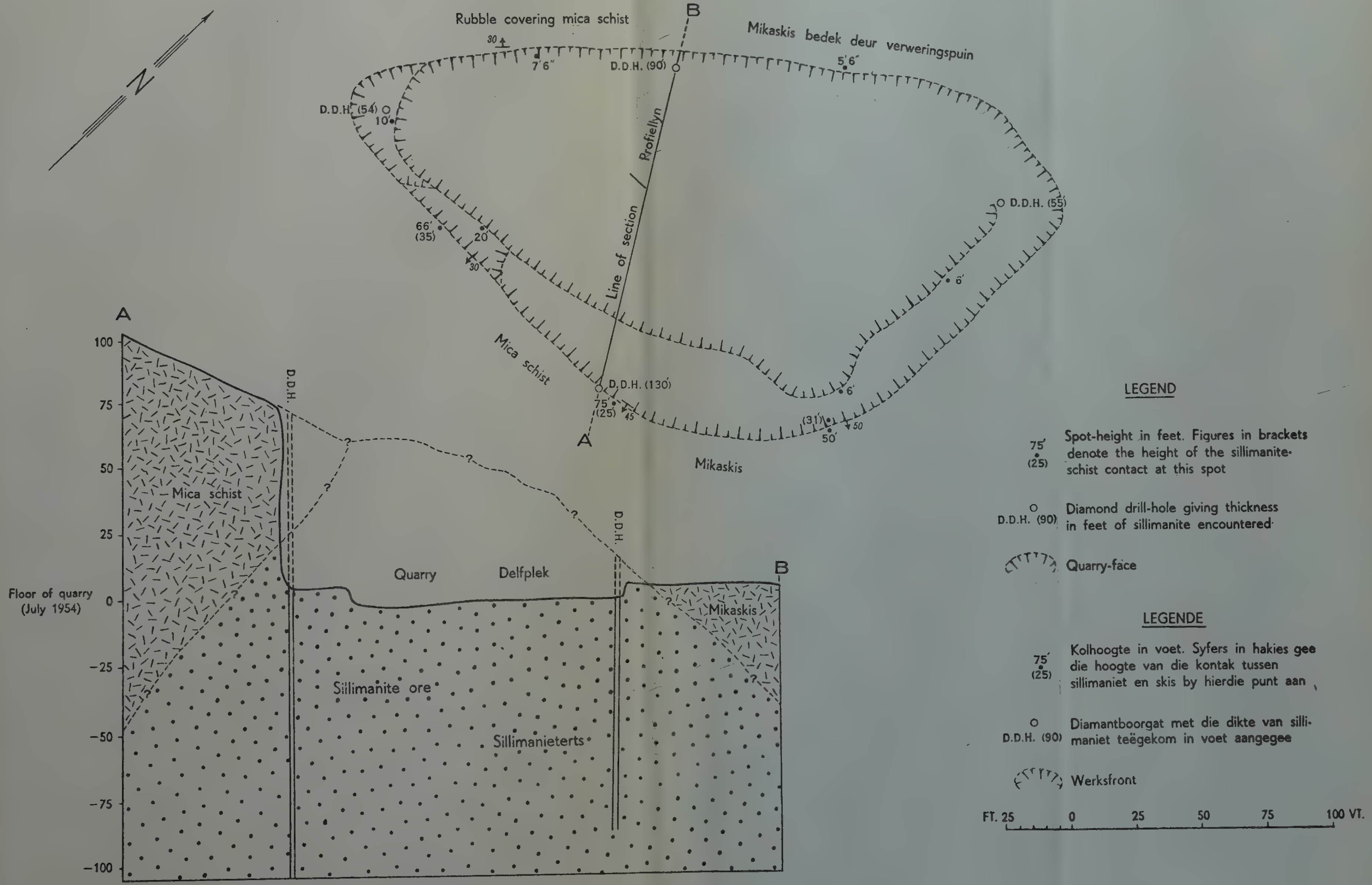
Plate VII.—Sillimanite Deposit No. 7. Note large number of residual sillimanite boulders covering the slope.

Plate VIII.—Sillimanite Deposit No. 7. Taken edge-on from top. Note broken sillimanite ready for shipping.

FOLDER 1
VOUBLAD

REPRESENTATION OF SILLIMANITE DEPOSIT NO. 1 AND QUARRY ON HOTSON

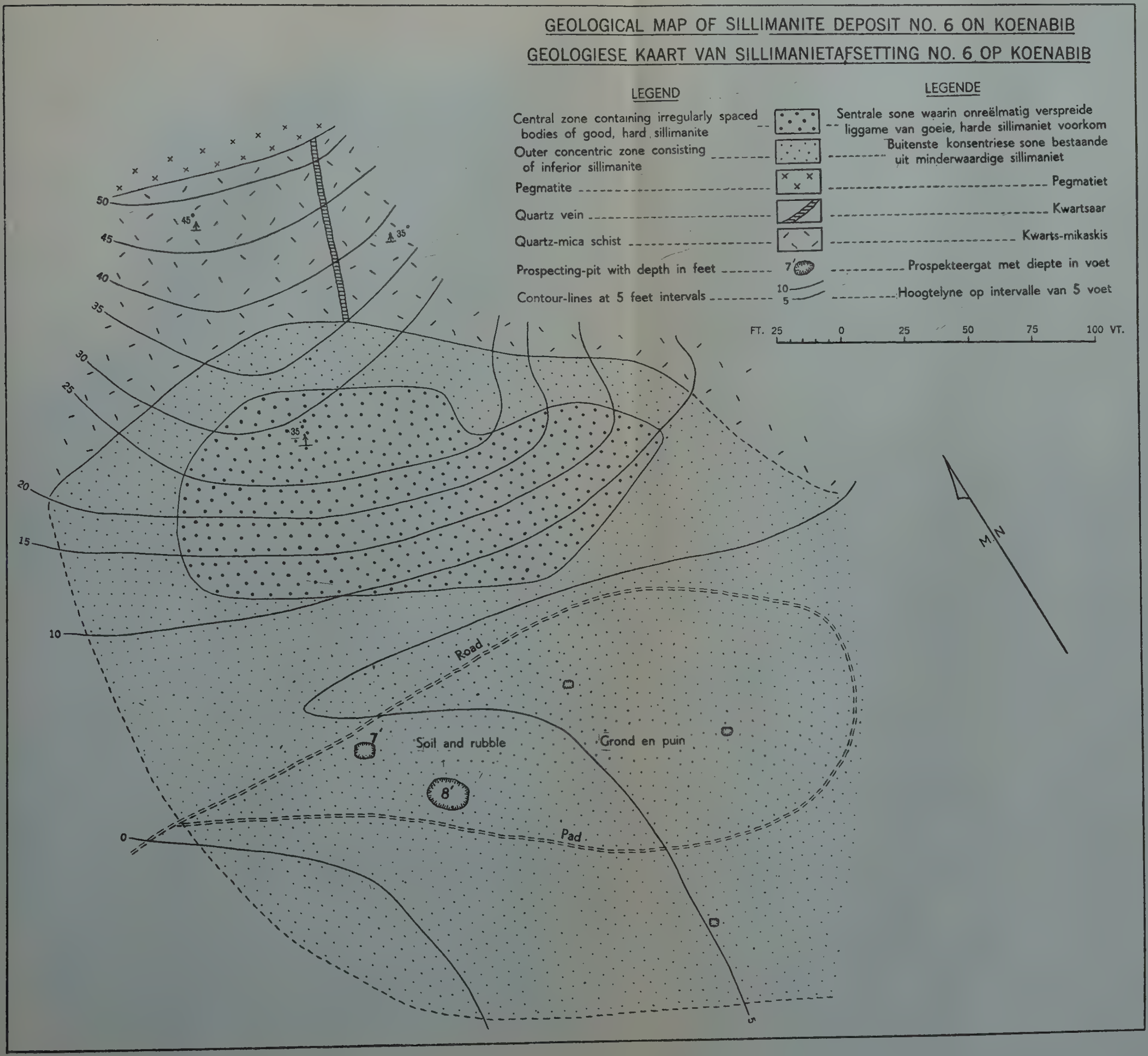
VOORSTELLING VAN SILLIMANIETAFSETTING NO. 1 EN DELFPLEK OP HOTSON

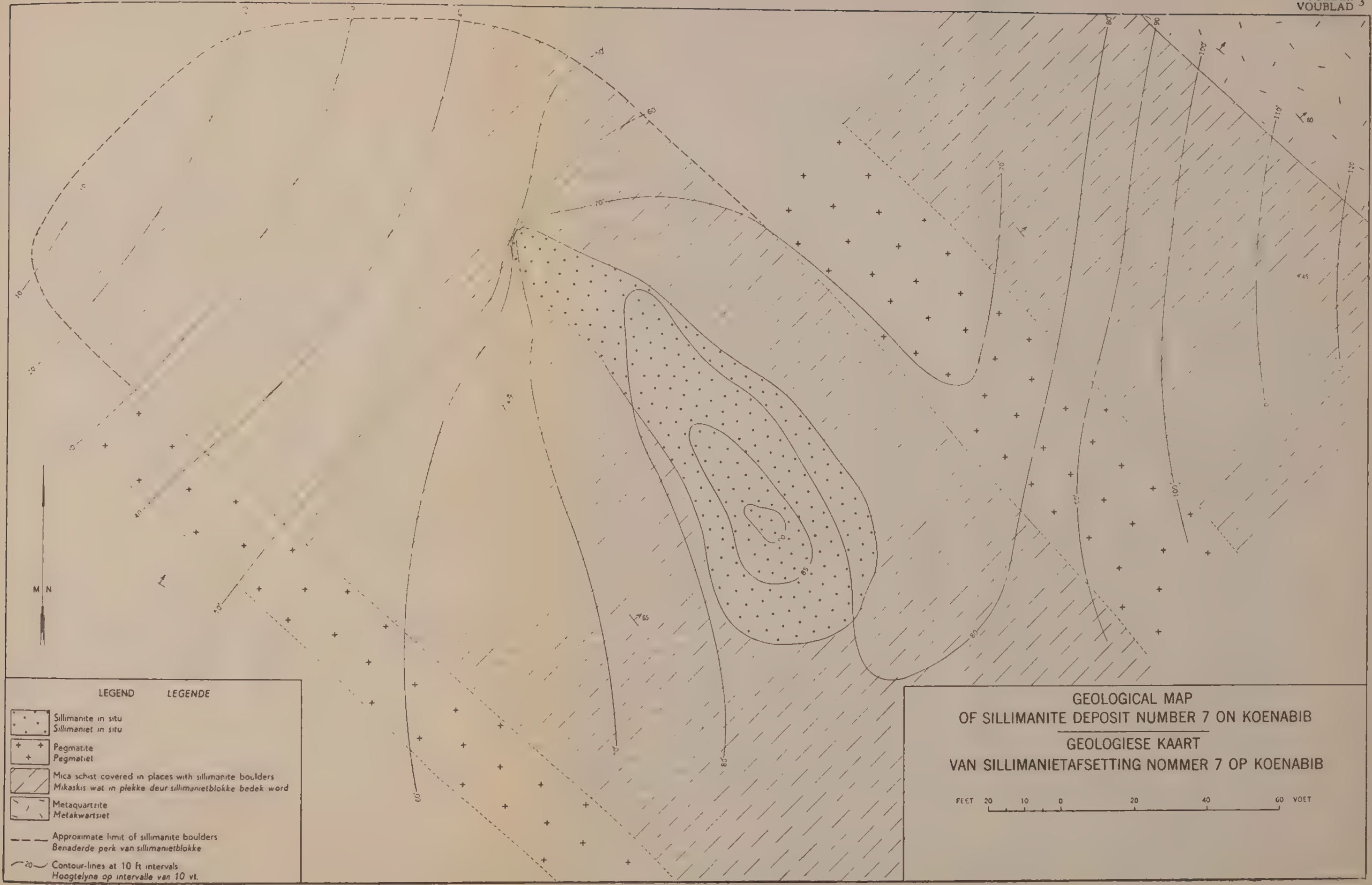

N
B
Rubble covering mica schist
Mikaskis bedek deur verweringspuin
30
7'6"
D.D.H. (90)
5'6"
D.D.H. (54)
10
Profiellyn
Line of section
66'
(35)
20
30
D.D.H. (55)
6'
Mica schist
D.D.H. (130)
75'
(25)
45
6'
(31)
50'
50
A
Mikaskis
A
100
75
50
25
Floor of quarry
(July 1954)
0
-25
-50
-75
-100
D.D.H.
Mica schist
?
Quarry
Delfplek
D.D.H.
B
Mikaskis
Sillimanite ore
Sillimanieterts
LEGEND
75'
(25)
Spot-height in feet. Figures in brackets denote the height of the sillimanite-schist contact at this spot
D.D.H. (90)
Diamond drill-hole giving thickness in feet of sillimanite encountered
Quarry-face
LEGENDE
75'
(25)
Kolhoogte in voet. Syfers in hakies gee die hoogte van die kontak tussen sillimaniet en skis by hierdie punt aan
D.D.H. (90)
Diamantboorgat met die dikte van sillimaniet teëgekom in voet aangegee
Werksfront
FT. 25
0
25
50
75
100 VT.

SECTION A—B
PROFIEL A—B

GEOLOGICAL MAP OF SILLIMANITE DEPOSIT NO. 6 ON KOENABIB

GEOLOGIESE KAART VAN SILLIMANIETAFSETTING NO. 6 OP KOENABIB


LEGEND
LEGENDE
Central zone containing irregularly spaced bodies of good, hard sillimanite
Sentrale sone waarin onreëlmatig verspreide liggame van goeie, harde sillimaniet voorkom
Outer concentric zone consisting of inferior sillimanite
Buitenste konsentriese sone bestaande uit minderwaardige sillimaniet
Pegmatite
Pegmatiet
Quartz vein
Kwartsaar
Quartz-mica schist
Kwarts-mikaskis
Prospecting-pit with depth in feet
7'
Prospekteergat met diepte in voet
Contour-lines at 5 feet intervals
10
5
Hoogtelyne op intervalle van 5 voet
FT. 25 0 25 50 75 100 VT.
M.N
50
45
40
35
30
25
20
15
10
0
5
45°
35°
35°
Road
Pad
Soil and rubble
Grond en puin
7
8'

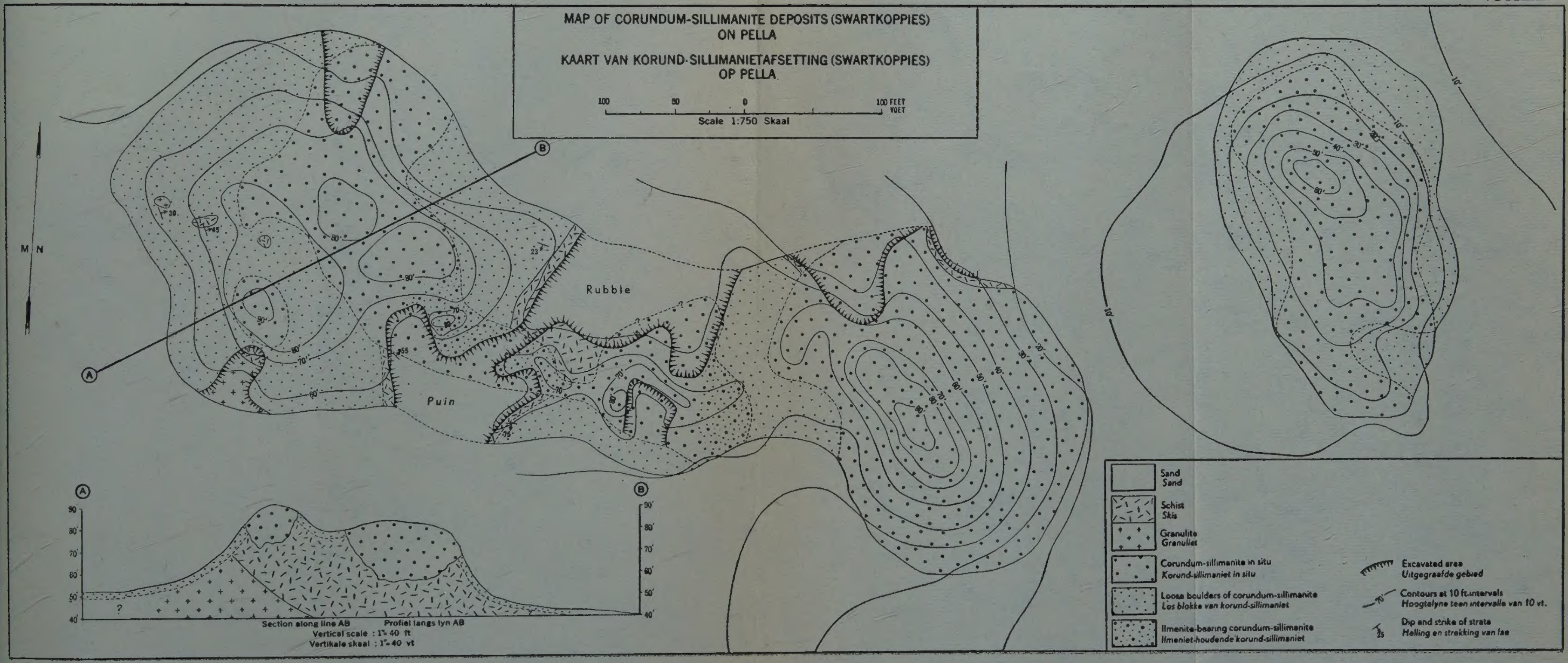


GEOLOGICAL MAP
OF SILLIMANITE DEPOSIT NUMBER 7 ON KOENABIB

GEOLOGIESE KAART
VAN SILLIMANIETAFSETTING NOMMER 7 OP KOENABIB

LEGEND LEGENDE
Sillimanite in situ
Sillimaniet in situ
Pegmatite
Pegmatiet
Mica schist covered in places with sillimanite boulders
Mikaskis wat in plekke deur sillimanietblokke bedek word
Metaquartzite
Metakwartsiet
Approximate limit of sillimanite boulders
Benaderde perk van sillimanietblokke
Contour-lines at 10 ft intervals
Hoogtelyne op intervalle van 10 vt.
20
M N
FEET 20 10 0 20 40 60 VOET
60
70
80
85
90
100
110
120
65
45
10

FOLDER 4
VOUBLAD



MAP OF CORUNDUM-SILLIMANITE DEPOSITS (SWARTKOPPIES) ON PELLA

KAART VAN KORUND-SILLIMANIETAFSETTING (SWARTKOPPIES) OP PELLA

100
50
0
100 FEET
VOET
Scale 1:750 Skaal
M
N
A
B
Rubble
Puin
30
45
23
80
70
60
55
10
90
40
50
20
Ⓐ
Ⓑ
90
80
70
60
50
40
?
Section along line AB
Profiel langs lyn AB
Vertical scale : 1"= 40 ft
Vertikale skaal : 1"= 40 vt
Sand
Sand
Schist
Skis
Granulite
Granuliet
Corundum-sillimanite in situ
Korund-sillimaniet in situ
Loose boulders of corundum-sillimanite
Los blokke van korund-sillimaniet
Ilmenite-bearing corundum-sillimanite
Ilmeniet-houdende korund-sillimaniet
Excavated area
Uitgegraafde gebied
Contours at 10 ft. intervals
Hoogtelyne teen intervalle van 10 vt.
Dip and strike of strata
Helling en strekking van lae
25